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14. ABSTRACT

This is the final technical report for contract number F49620-01-1-0307 with the Air Force Office of Scientific Research. The report provides information about the inductively coupled plasma system that was acquired under this contract. The system is a Unaxis Versalock 700, a production level cluster tool for dry etch and dielectric deposition.

The tool provides up to 3 process chambers. Currently two of them are in function in our facility: chamber one has been arranged for dry etching of compound semiconductors and chamber two for dielectric deposition (SiN_x and SiO_2). We will describe the system and highlight the added value that the system brought to our cleanroom.

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In the past all of the dry etching tools available at our facility were RIE tools. We had a custom, loadlocked chlorine-based system, a methane/hydrogen-based system, a fluorine-based system MRC 51, and a programmable, loadlocked chlorine-based system. The only ICP system available was a SiRIE ICP based fluorine etcher for Bosch MEMs processes, inadequate for common etching. Our intention is to reduce our use of RIE equipment in favor of the ICP one. Recently we installed two ICP machines: the Unaxis Versalock 700 object of this report (chlorine chemistry), and a Panasonic E640 (chlorine and fluorine chemistries).

Typical advantages of ICP over RIE are: lower operating pressure (allowing for wider operating window for vertical features), better selectivities, better uniformity, lower damage (at parity of self bias). Moreover the ability to operate the machine at high temperature (160°C or higher) allows for fast etching of indium phosphide (indium is poorly volatile at room temperature). Currently we are developing recipes for InP, GaAs, and GaN material systems. We will shortly report a couple of recent results obtained on indium phosphide and gallium arsenide. In Fig. 1 is shown an SEM picture of results obtained on InP at our facility. The developed recipe was: pressure 7mTorr, RF power 100W, ICP power 500W, 10sccm Cl_2, 70sccm N_2, 200°C substrate temperature. The etch rate was 0.27 μm/min, the etch mask was SiO_2, and the etch selectivity over the mask was 7. As shown in Fig. 1, the recipe was developed in order to obtain high aspect ratio etches. In Fig. 2 are shown results on AlInGaAs/AlInAs photonic structures, were deep mesa etches (and therefore high selectivities to the masking material) are required. Operating conditions were: chamber pressure 7mTorr, RF power 75W, ICP power 900W, Cl_2 flow 15sccm, N_2 flow 45sccm, substrate temperature 200°C. The etch mask was SrF_2, etch selectivity was 120.

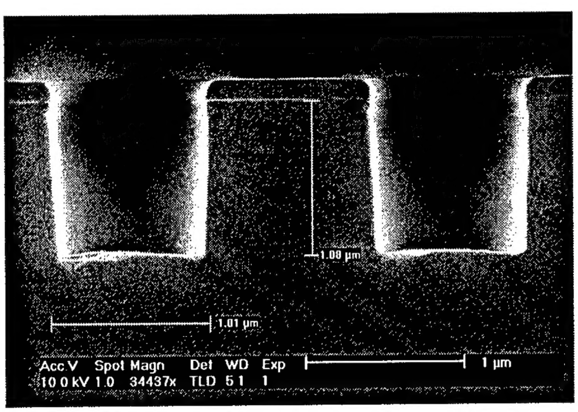

Fig. 1: High aspect ratio etch of InP

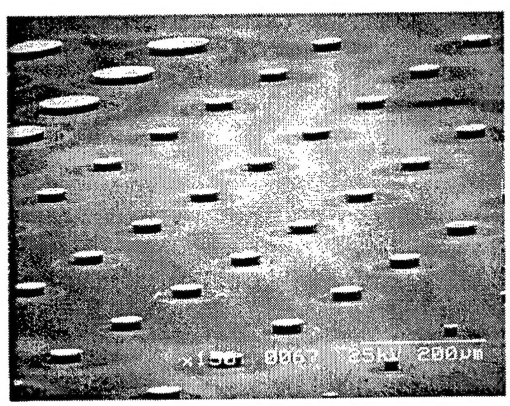

Fig. 2: Highly mask selective AlInGaAs/AlInAs etch (SrF_2 mask)

Chamber two: HDP deposition

Chamber two is configured as an high density plasma deposition (HDP or HDPCVD) chamber with 1000W ICP power and 500W RF substrate power. The gases available for this chamber are SiH_4, NH_3, N_2, O_2, Ar, N_2, and SF_6. The first six gases are used for deposition, the last one for dry cleaning the chamber after the deposition. Maximum gas flows are 500, 50, 500, 100, 100, 20, and 200 sccm, respectively. The chamber is used for depositing SiO_2, Si_3N_4, or SiO_xN_y dielectric films. Both plasma enhanced chemical vapor deposition (PECVD) and high density plasma deposition (HDP) are possible in this chamber.

In the past our facility was equipped only with a low density PECVD system. The ability to use an auxiliary ICP coil allows for improved plasma density and higher quality material. This system is currently the only system at our facility able to perform HDP. Typical advantages of HDP over PECVD are: higher deposition rates, lower plasma induced damage, higher material quality, lower operating temperature at parity of material quality.

In Fig. 3 is reported an SEM image of a HDP silicon nitride film deposited on indium phosphide. The film was deposited at 250°C, chamber pressure was 15 mTorr, RF power 5 W, ICP power 400 W, N_2/SiH_4 flows were 4/290 sccm. The higher quality of the film compared to the corresponding PECVD film can be inferred from Table 1, were buffered HF (hydrofluoric acid) etch rates of the films are compared. Lower numbers correspond to higher material quality.

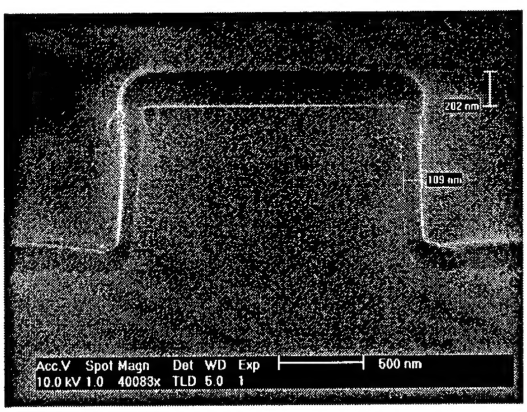

Fig. 3: SiNx film deposited on patterned InP wafer (trench depth 1 μm and trench width 2.9μm), using the Unaxis HDP deposition system

	SiN_x Film		
	100 °C (HDP)	250 °C (HDP)	250 °C (PECVD)
Refractive Index	2	2	N/A
Deposit. rate (nm/min)	24.9	23.5	~10
BHF etch rate (nm/min)	20	7	36
On sidewall/on top film thickness ratio	N/A	0.54	0.74
Stress: 200 nm thick film on Si Substrate (MPa)	-2123	-2188	260

Table 1: Comparison between HDP and PECVD results for SiN films, as obtained on the machines available at our facility.

Conclusions

The Unaxis Versalock 700 is flexible tool for ICP etching and HDP deposition. Currently it is the only system in our facility able to perform HDP deposition, and it is the only system specialized in chlorine ICP etching of indium phosphide. We believe ICP etching will provide evident benefits to the research efforts of our university on compound semiconductors (InP, GaN, and GaAs). The higher quality of the dielectrics deposited by HDP will be useful for capacitor integration and dielectric passivation in the same material systems.